

# **Enhanced *In Situ* Remediation of Hydrogen Release Compound (HRC<sup>®</sup>) and Hydrogen Release Compound-Extended Release (HRC-X<sup>™</sup>)**

**Anna Willett and Stephen S. Koenigsberg**  
**Regenesis**  
**San Clemente, CA**



# Company History

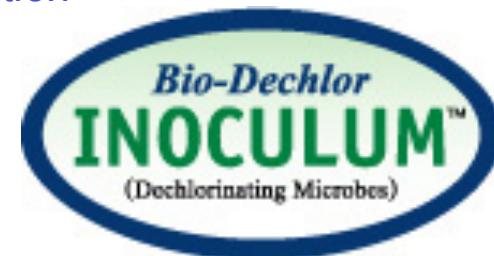
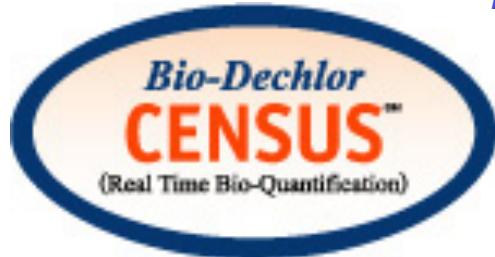
- Founded in 1994
- First product, Oxygen Release Compound (ORC®), pioneered the market for injectable time release electron acceptors. Major contributor to the rise of accelerated natural attenuation strategies
- To date – 6 products and employees covering the U.S., Canada, Europe, Asia, and Australia





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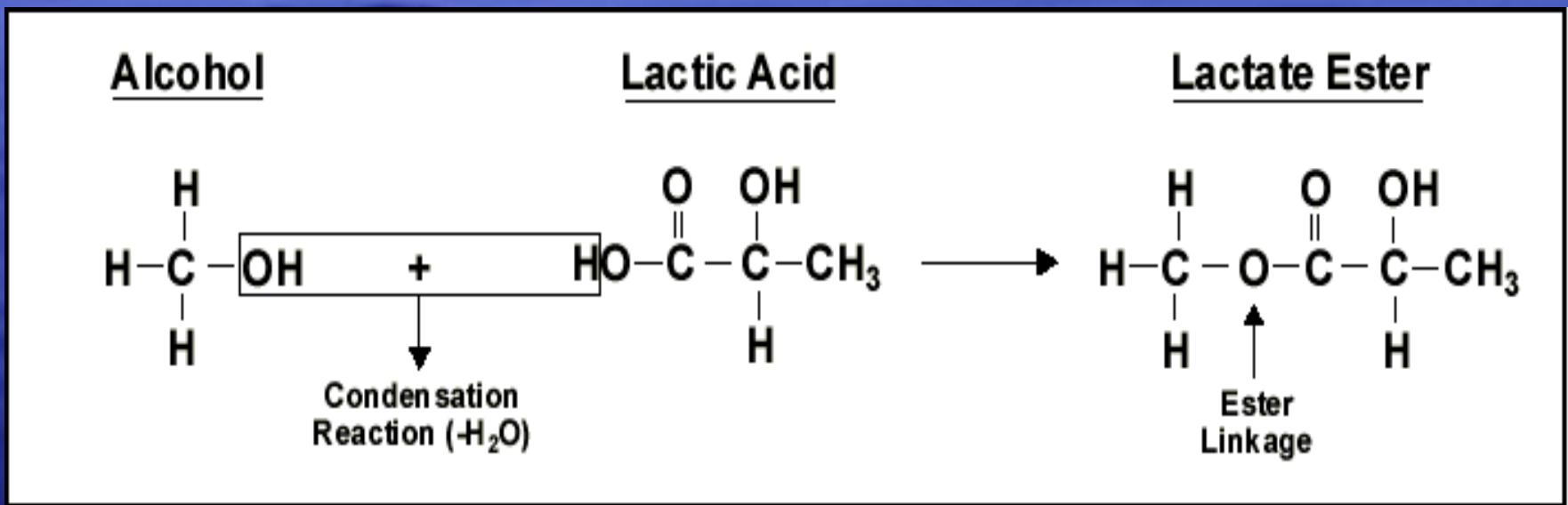
*Leaders in Accelerated Natural Attenuation*



*[eXtended release formula]*

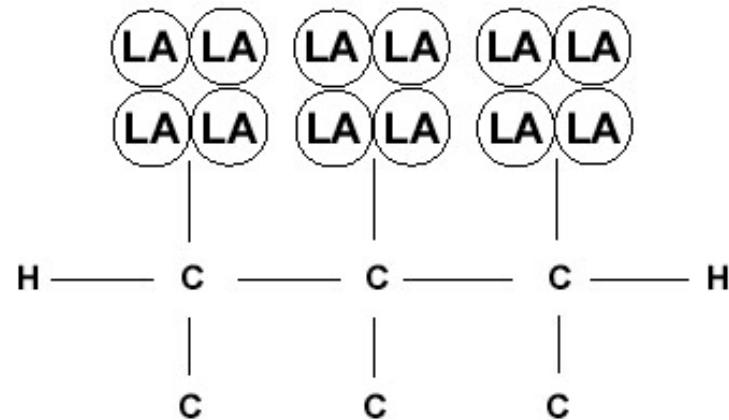
# What is HRC?

- HRC consists of polylactate esterified to glycerol
- When injected into an aquifer, HRC slowly releases lactic acid



# What is HRC?

## HRC®- Glycerol Polylactate (GPL)



- Lactic acid and its metabolic products are used as electron donors for reductive biodegradation processes
- HRC has a field longevity of 12 to 18 months

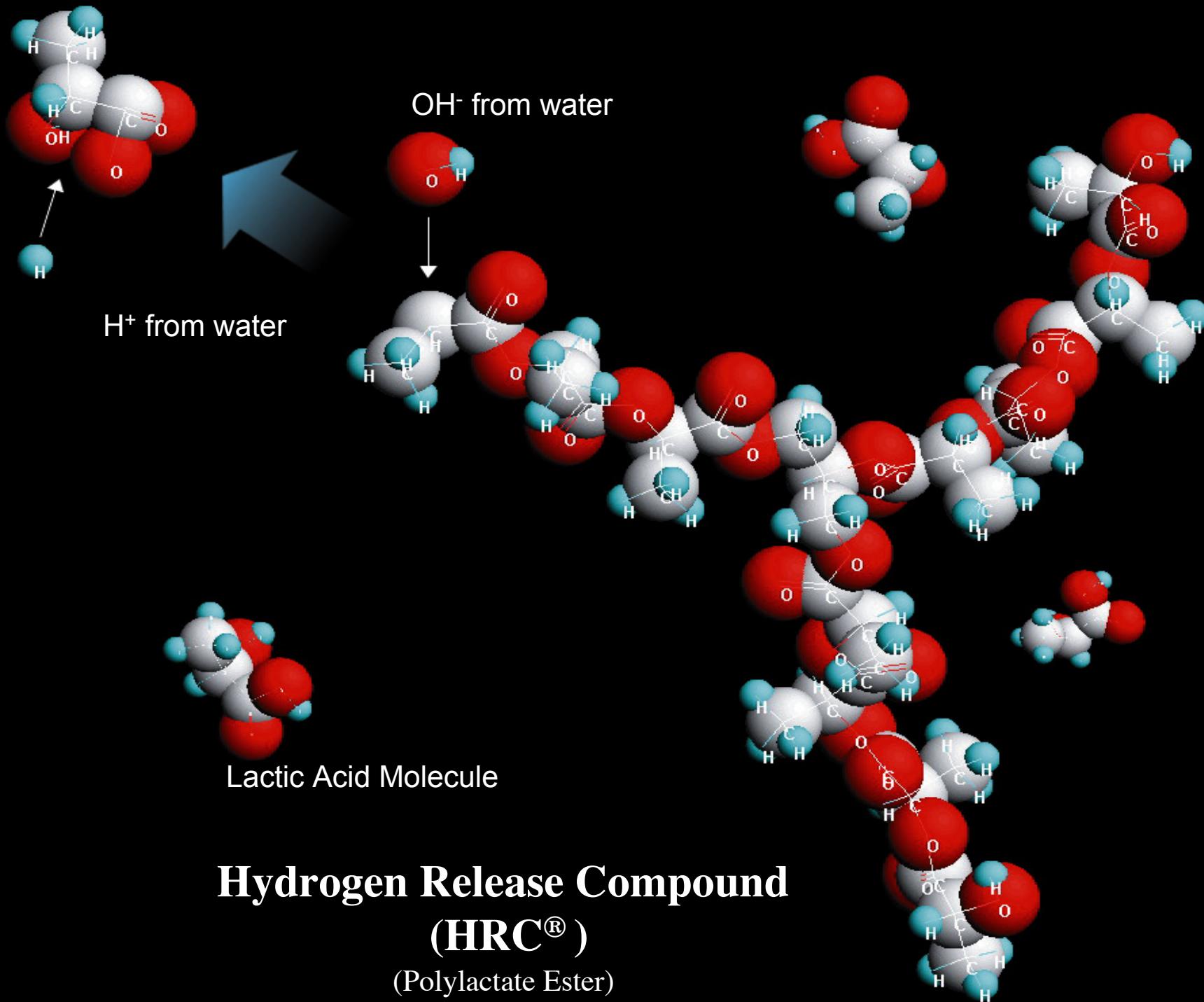
$\text{H}^+$  from water

$\text{OH}^-$  from water



Lactic Acid Molecule

**Hydrogen Release Compound  
(HRC<sup>®</sup>)  
(Polylactate Ester)**

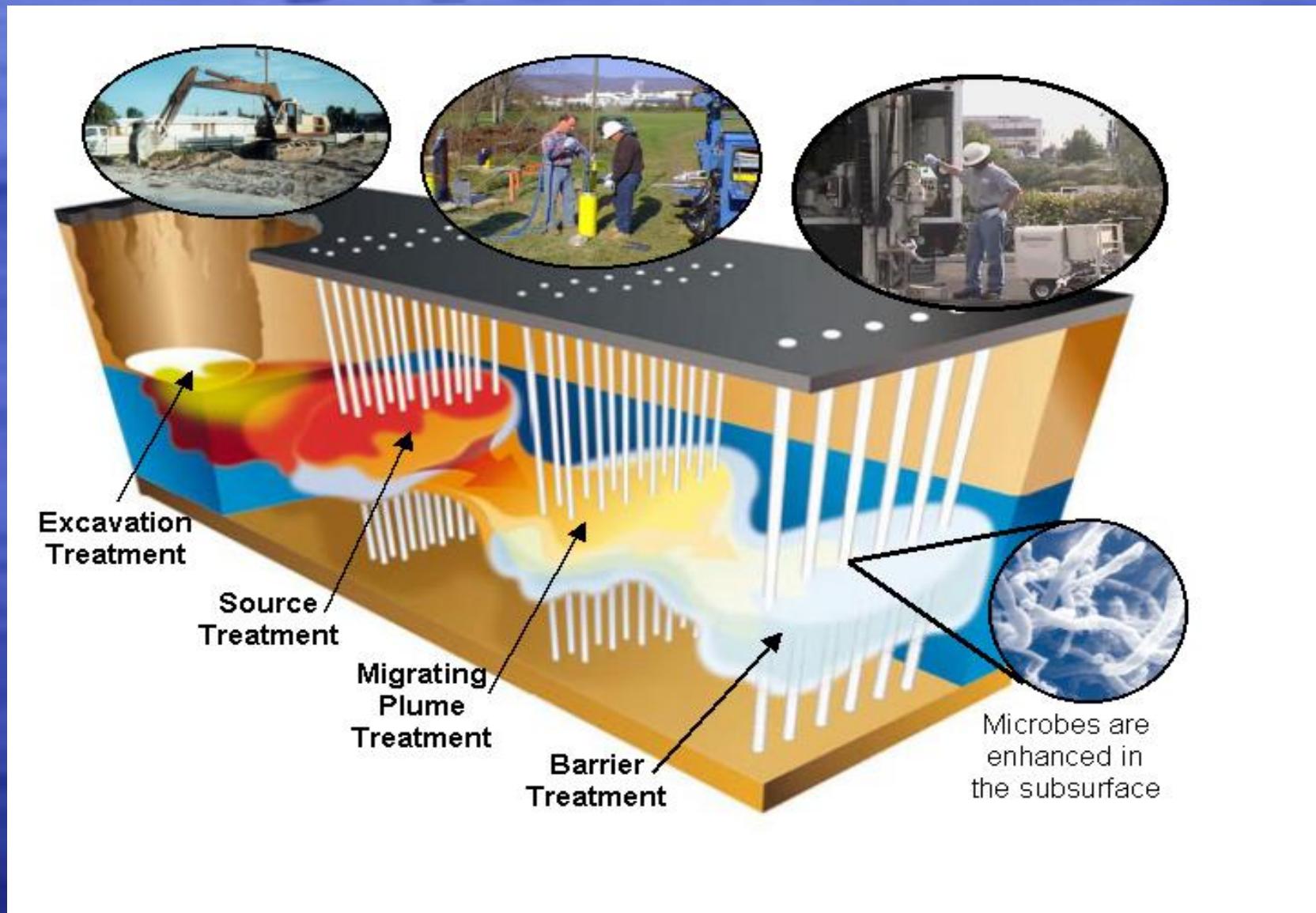


# Hydrogen Release Compound – Extended Release (HRC-X)

- A highly concentrated electron-donor for bioremediation
- Viscosity of 200,000 cP (HRC is 20,000 cP)
- Field longevity of at least 3 years



# Methods of Application



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# HRC Field Application



HRC is a viscous but injectable substance



HRC is injected into the aquifer using direct-push technologies

  
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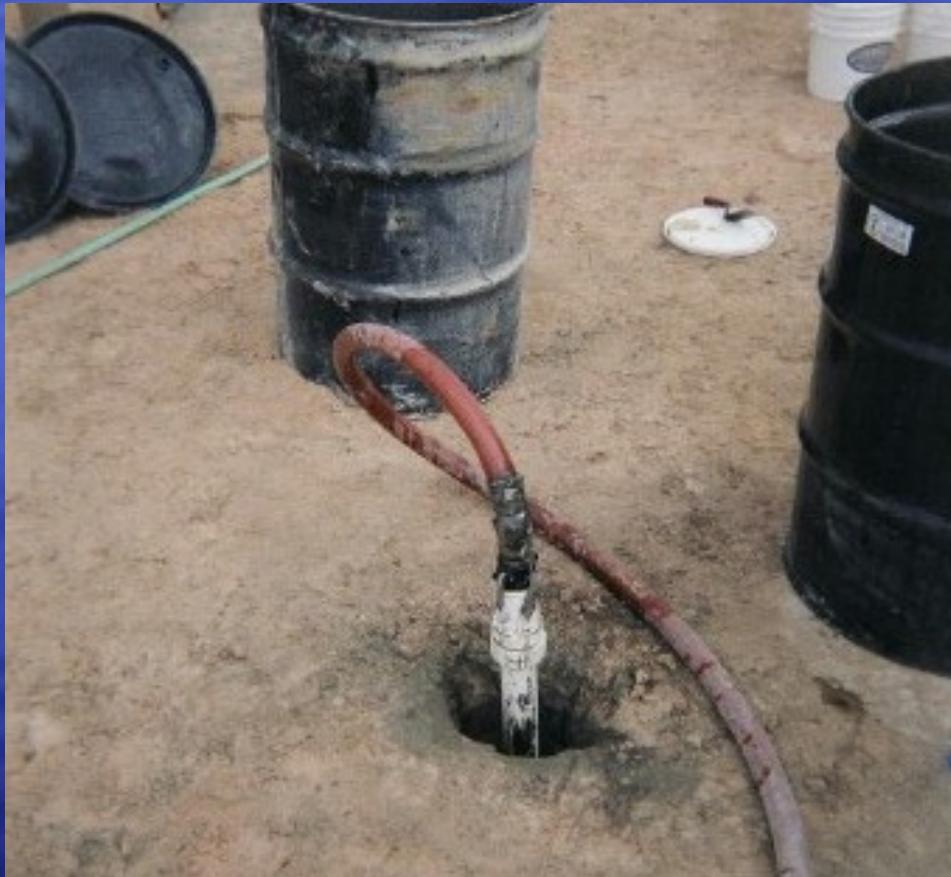
The logo consists of a stylized blue and white swoosh graphic followed by the word "REGENESIS" in a bold, black, sans-serif font.

# Heating Before Injection



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# Injection and Application



# Distribution of HRC

- HRC is both “static” and slowly soluble. It stays in place as it releases lactic acid.
- High initial concentrations of lactic acid at the surface of the HRC-water interface drive mass transfer

# **Longevity of HRC**

## **“How long does it last?”**

- The degree of complexity and esterification of the molecule are key factors in its longevity
- Longevity is a function of certain biological and geochemical features of the aquifer
  - microbial population
  - groundwater flow rate

# **Compounds Treatable With HRC**

- Chlorinated Organics (ethenes, ethanes, etc.)
- Chlorinated Pesticides and Herbicides
- Nitrate
- Chromium
- Perchlorates
- Explosives

# Benefits of Slow Release Substrates

- Typically, no dedicated wells needed
- Rapid implementation
- Infrequent (if any) remobilizations/reapplications
- Minimize impact on current land uses
- Risks of fouling minimized
- Cost-Effective
  - No capital costs for systems
  - No operation & maintenance costs
  - Reduced installation costs

# **Benefits of HRC's Time-Release Feature**

- Accelerates natural attenuation by 10X to 100X reducing time to site closure
- Wide regulatory acceptance
  - environmentally safe
- Proven technology
  - Demonstrated by US EPA SITE program
  - Installed on >450 sites

# Results of a Successful Enhanced Reductive Dechlorination Pilot Test Under the U.S. EPA SITE Program



# Authors

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**(Brown and Caldwell, Golden, CO)**

Willard Murray  
**(Gloucester, MA)**



# Introduction – Fisherville Mill Site

- Pilot-scale study was conducted to determine the effectiveness of HRC to reduce TCE concentrations in groundwater at the Fisherville Mill site in Grafton, Massachusetts.
- Enhanced reductive dechlorination with HRC was selected as the treatment technology.

# Objectives

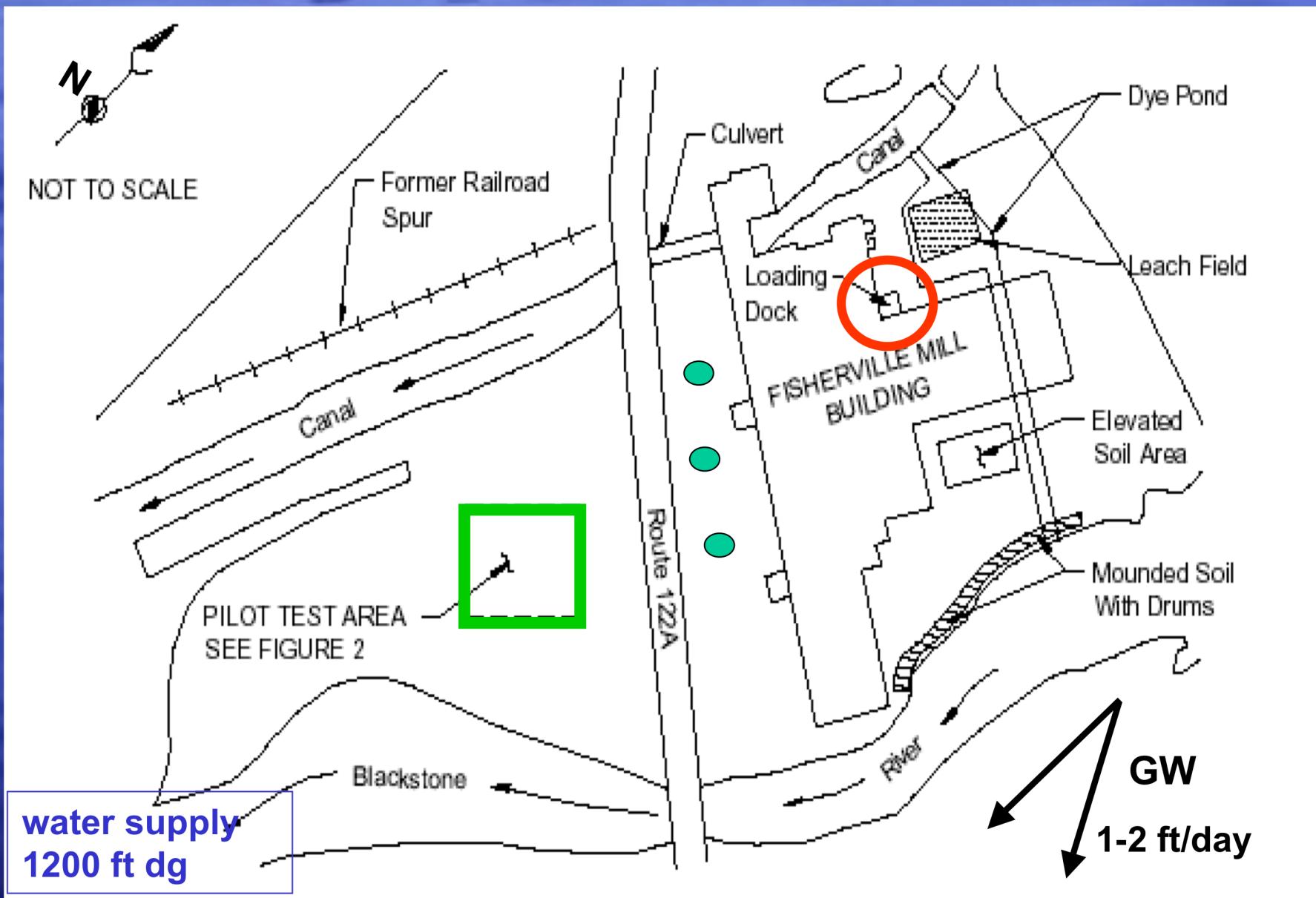
1. To demonstrate that HRC injection can:
  - remediate PCE, TCE, and other regulated daughter products to ethene.
  - control the further migration of contaminants, thus protecting downgradient receptors.
2. To determine:
  - the length of time over which HRC metabolites remain within the aquifer.
  - how widely the HRC metabolites are distributed and their effect on geochemical parameters.

# Site Background

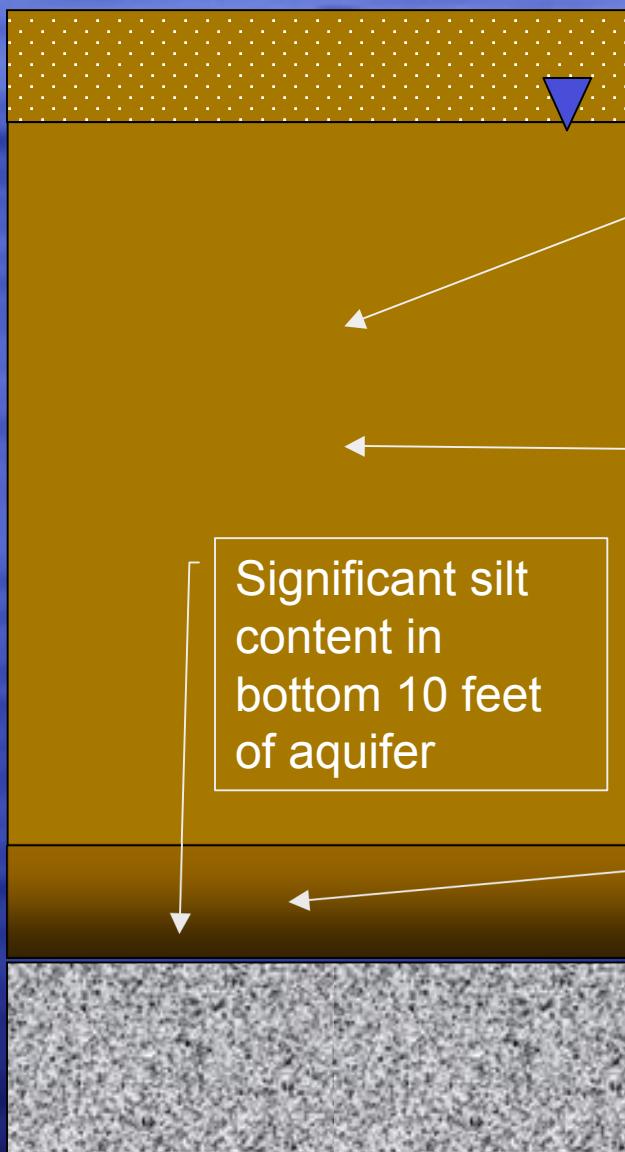
- 1862** Fisherville Mill was constructed and began producing cotton and woolen items.
- 1950** Fisherville Mill began producing steel racks, machine tool parts, plastics assembly, and aluminum lawn furniture.
- 1986** Site assessment in response to contamination in an adjacent canal was conducted. A chlorinated ethene plume was identified.
- 1996** Recovery wells for pump and treat operations were installed to protect the town of Grafton, MA drinking water supply.
- 1999** Fire completely destroyed the Fisherville Mill building and the groundwater treatment system



# Fisherville Mill Site Map



# Site Characteristics



The water table is 10 feet bgs with a 1 foot annual fluctuation due to recharge.

The aquifer is composed of 50 feet of fine to coarse sand and gravel alluvium bounded below by granitic bedrock.

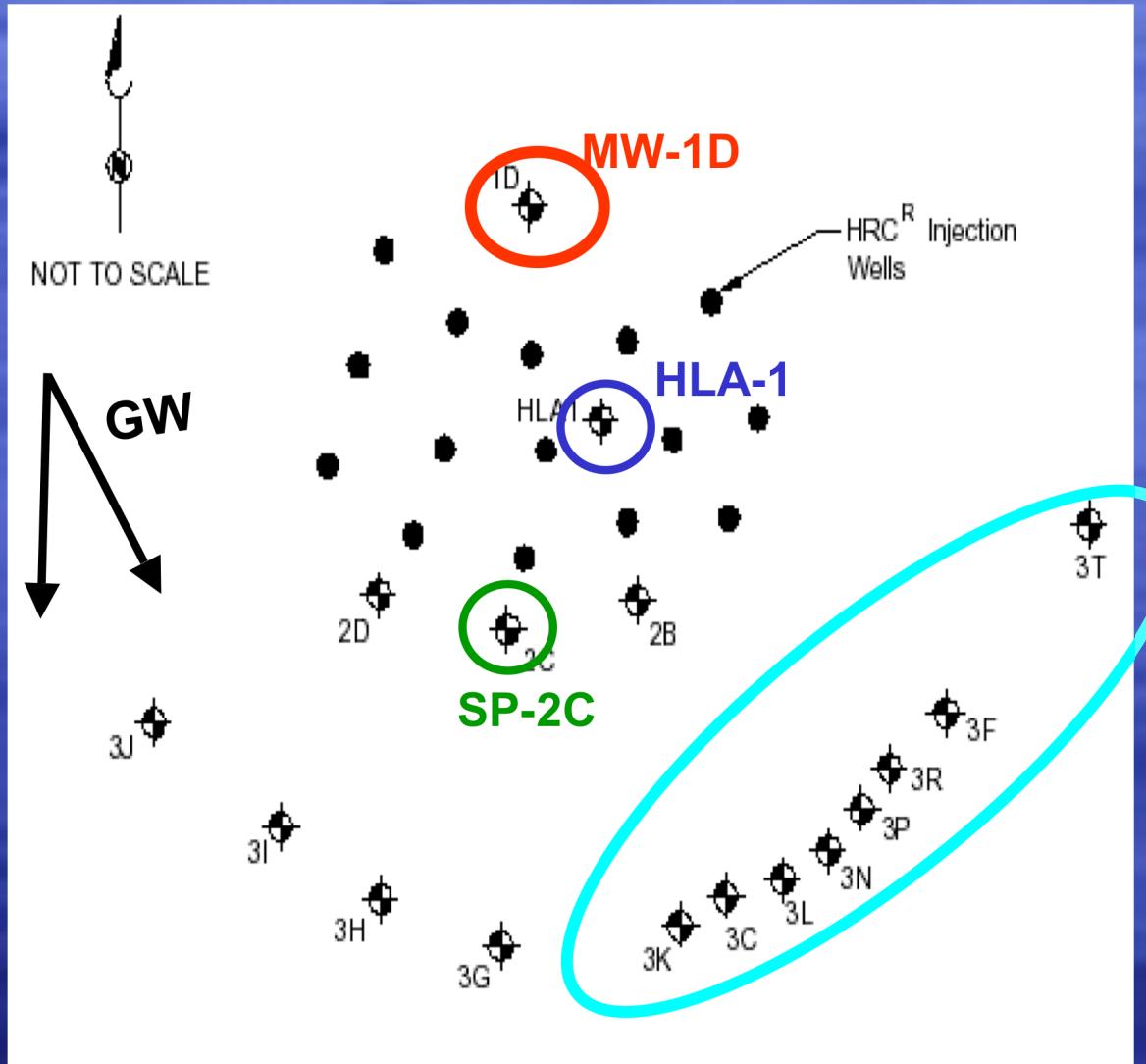
Beneath the mill building, wells screened in the upper 40 feet of the aquifer were low to non-detect for chlorinated ethenes.

Beneath the mill building, TCE concentrations exceeded 10,000 µg/L in the deepest 10 feet of the aquifer (40-50 feet bgs).

# Prior to HRC Injection

- Data collected over the 10-month period prior to HRC injection showed an increase in TCE in the pilot study area due to termination of the pump and treat system (input from upgradient source under Mill)
- TCE in MW-1D went from low levels to concentrations ranging from 1,300 ug/L to 2,600 ug/L (well is screened 40-50 feet bgs).
- Low levels of PCE, cis-DCE, and VC were also present.
- The limited extent of natural degradation indicated the potential of HRC to significantly accelerate chlorinated ethene bioremediation.

# HRC Injection Wells and Monitoring Wells

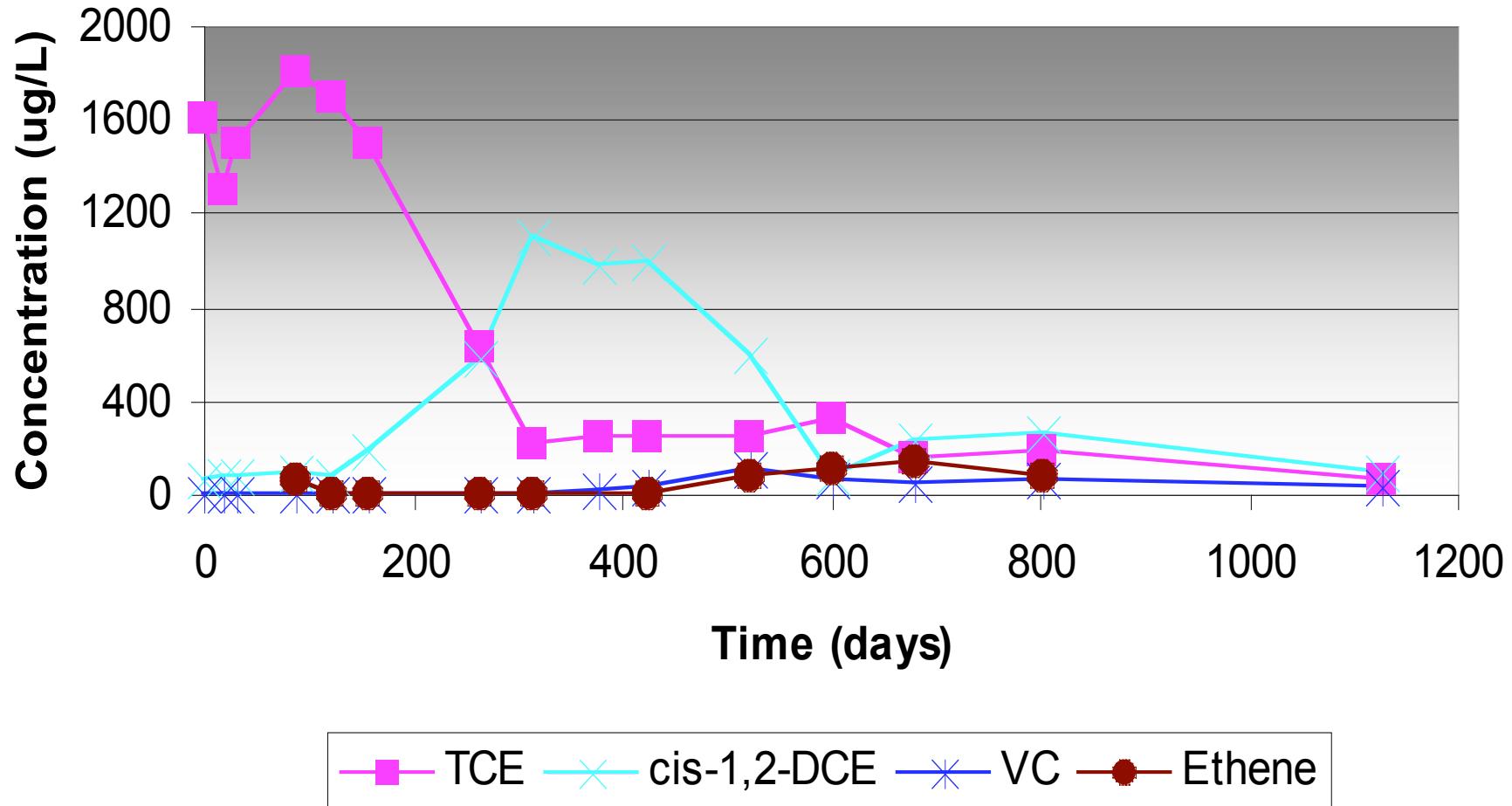


- 3 rows, 5 points
- 7 ft between points
- 5 ft between rows
- MW-1D 7 ft ug of HRC grid
- SP-2C 5 ft dg of HRC grid
- SP-3 wells are ~25 ft dg of HRC grid

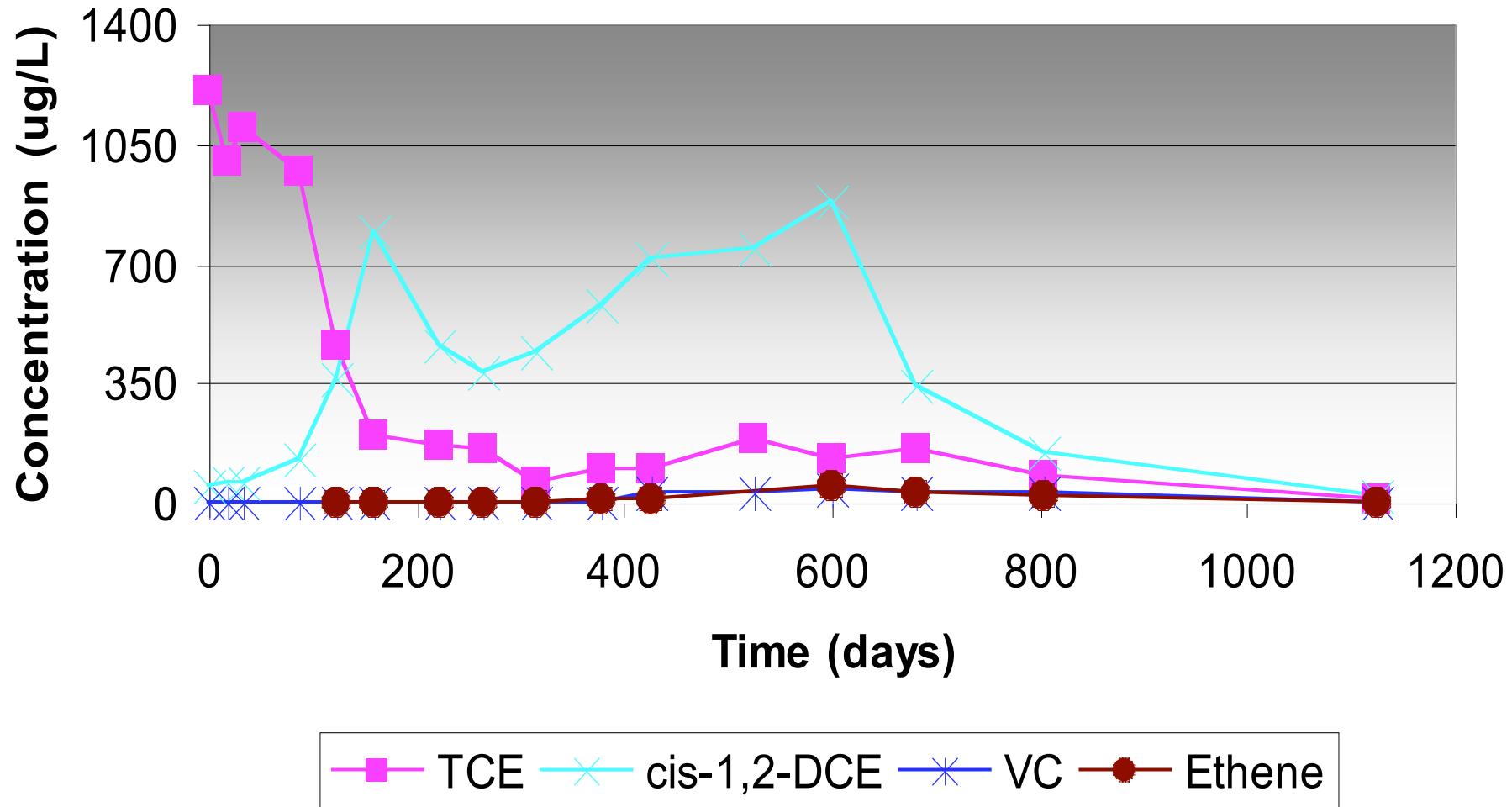
# HRC Injection

- HRC Primer and HRC were sequentially injected into each injection point, which consist of 2-inch schedule 80 PVC wells, at the rate of 4 lbs/vertical foot of HRC Primer and 6 lbs/vertical foot of HRC
- High loading rate of 10 lbs/ft of total electron donor is due to high groundwater velocity (low competing electron acceptors and low sorption due to sand lithology)

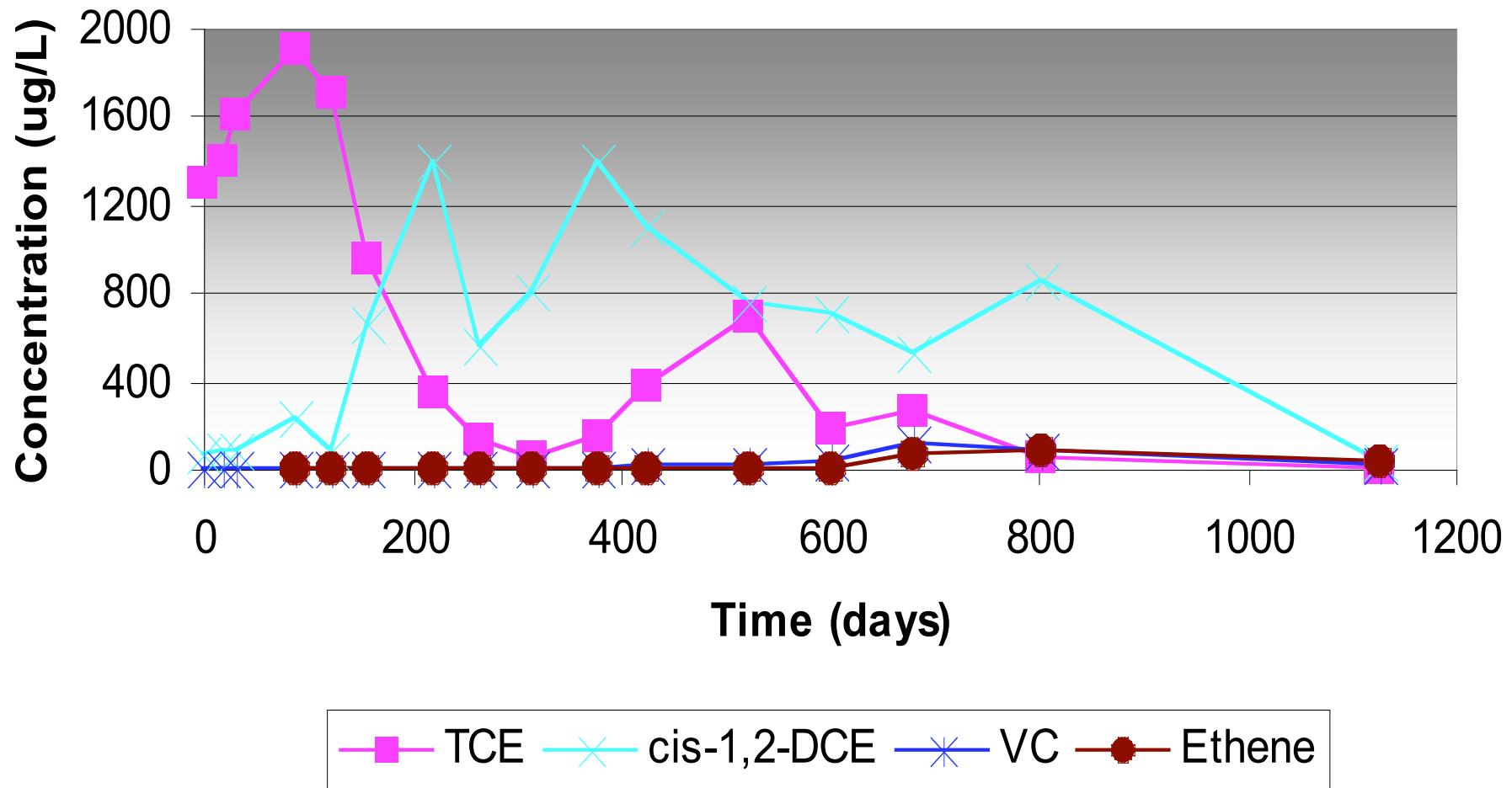
## Chlorinated Ethene Concentrations for HLA-1



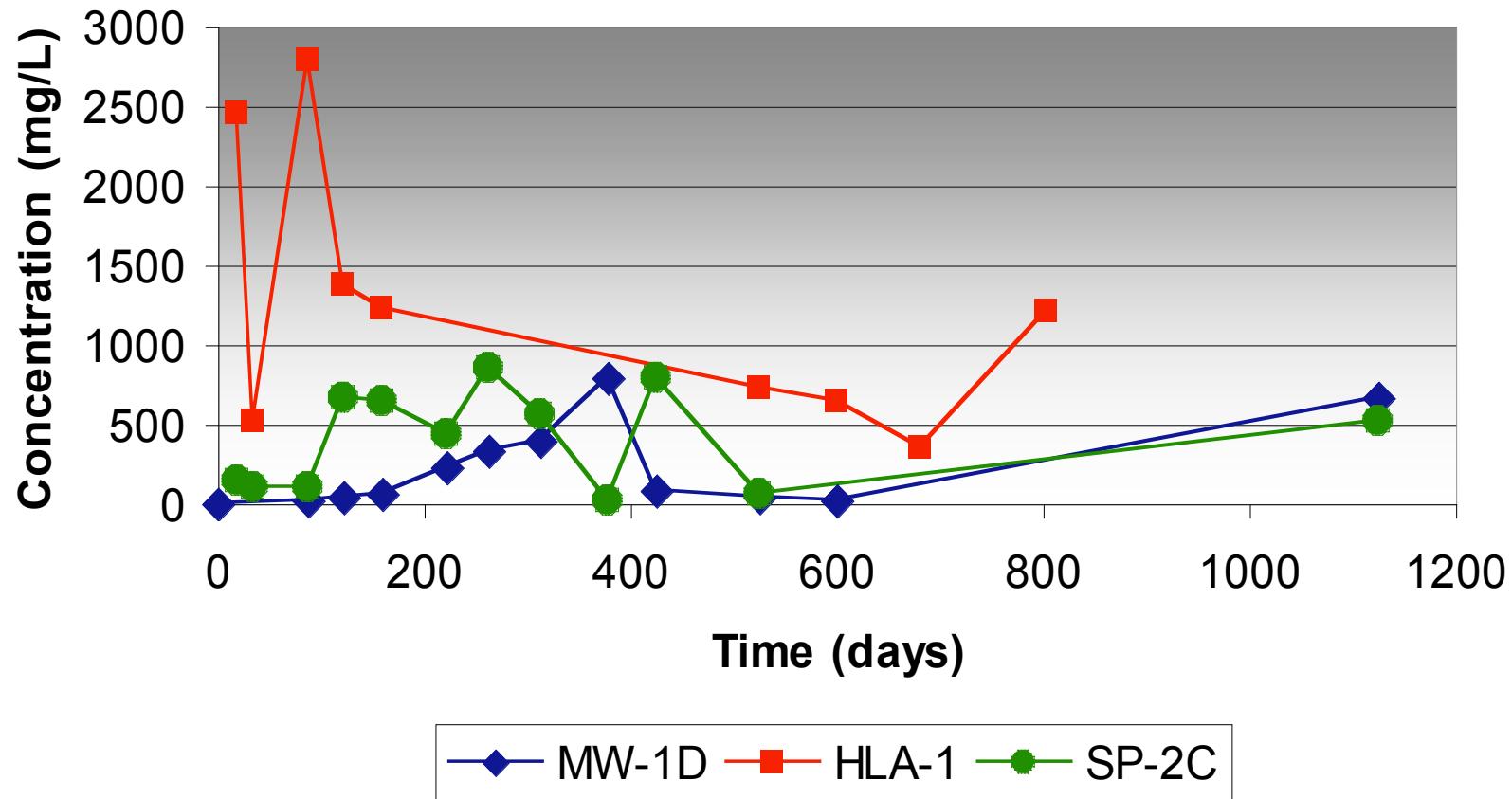
## Chlorinated Ethene Concentrations for SP-2C



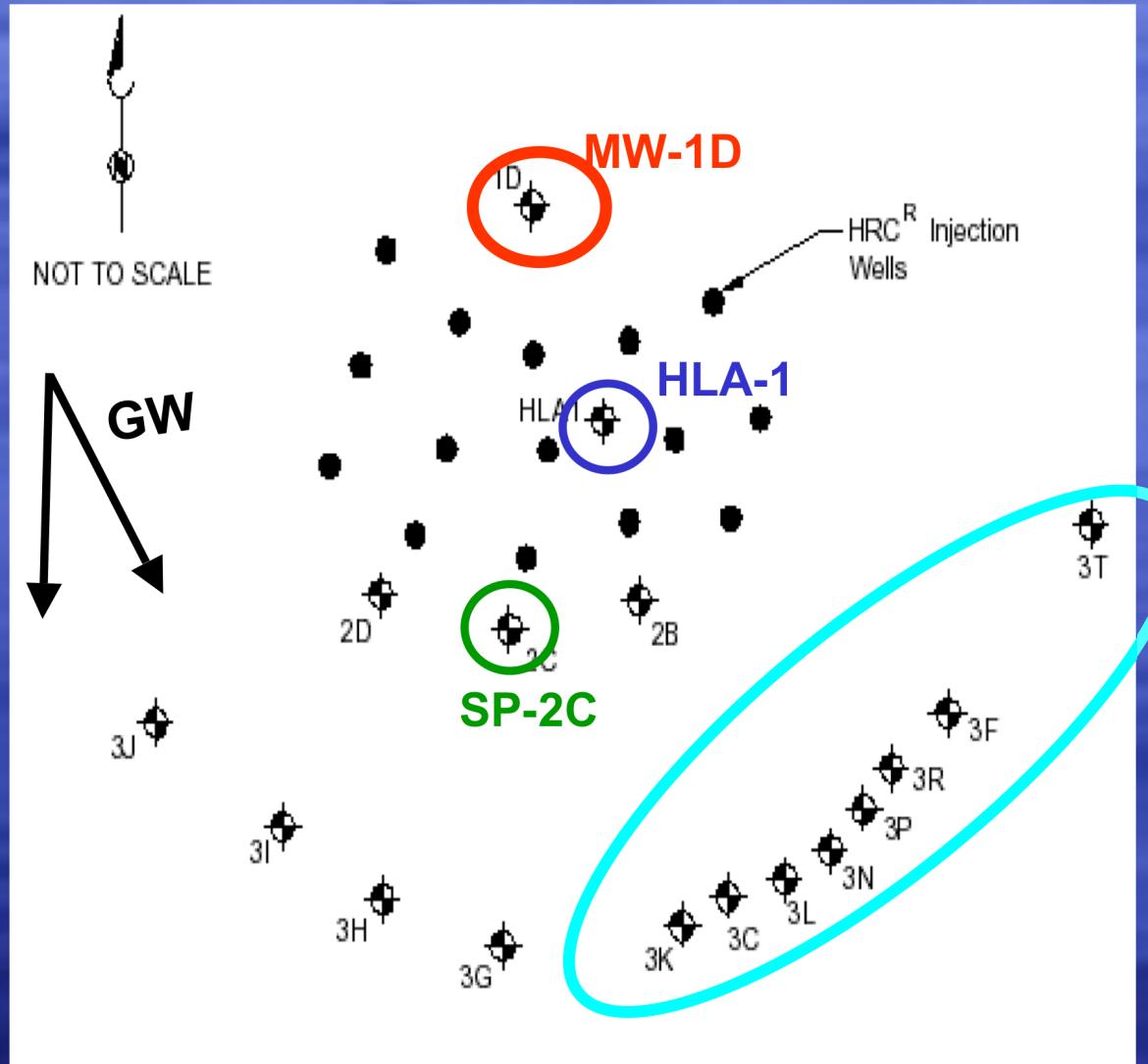
# Chlorinated Ethene Concentrations for MW-1D



## Total Organic Acids in Near Grid Wells

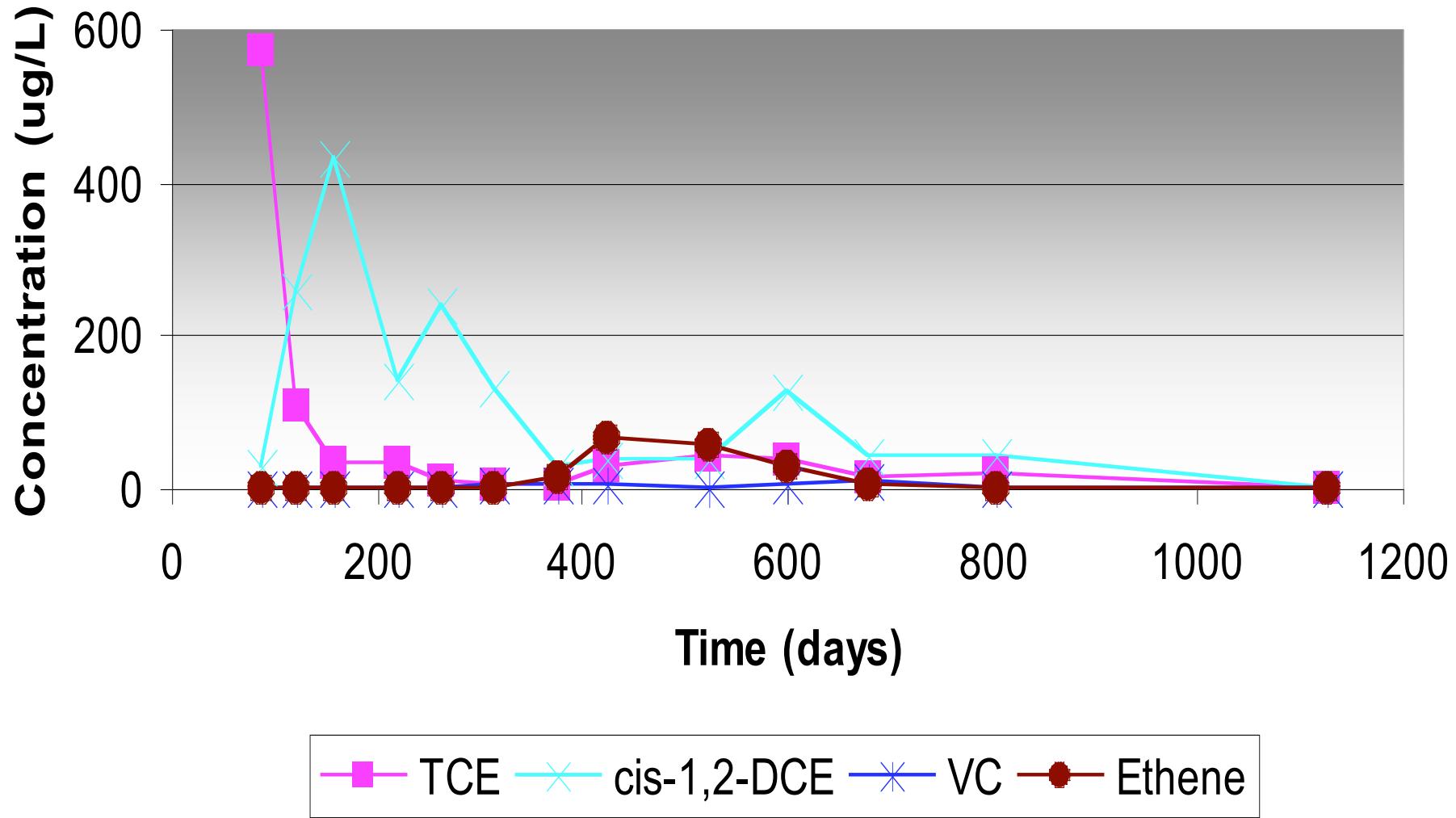


# HRC Injection Wells and Monitoring Wells



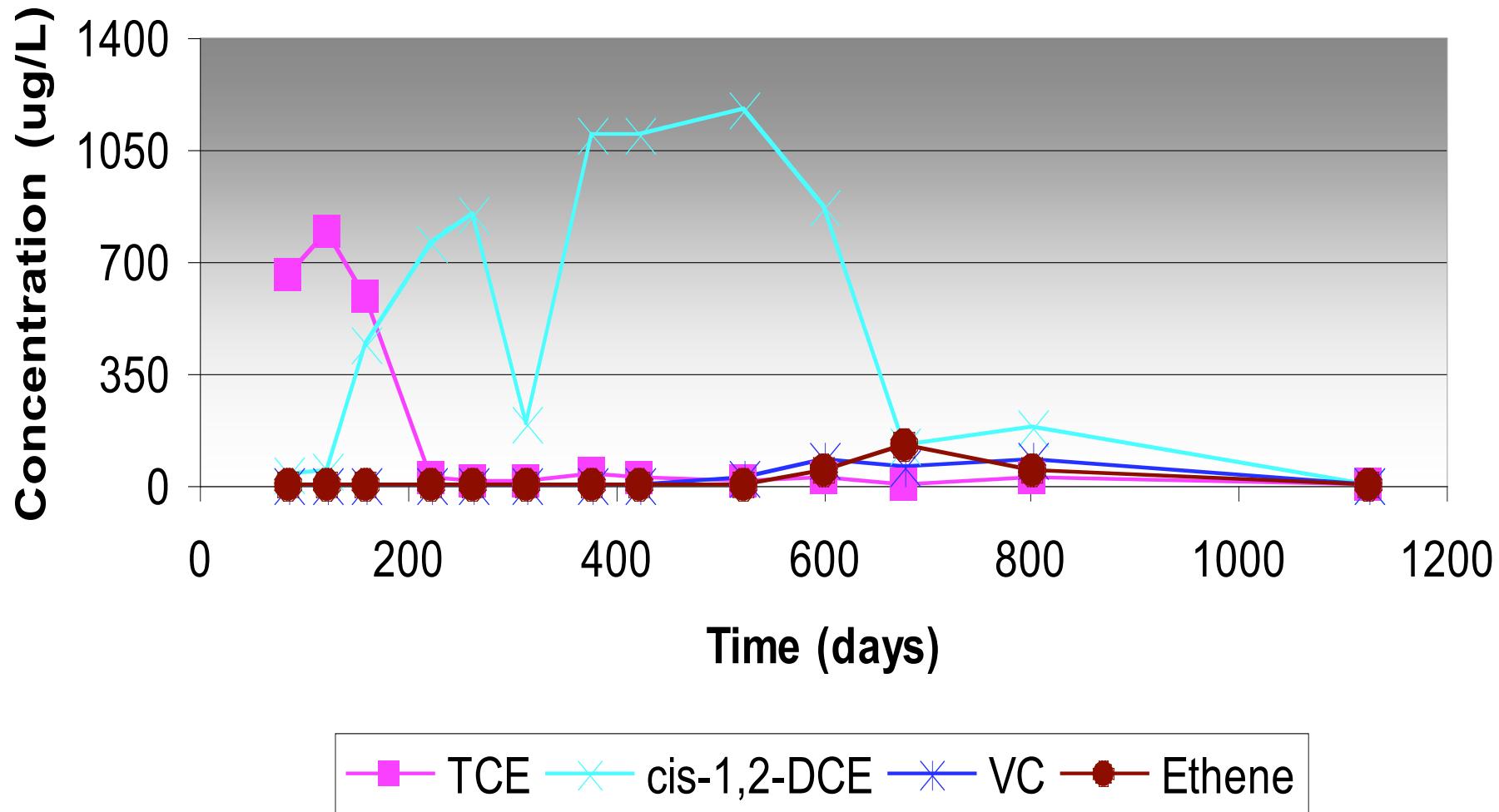
- 3 rows, 5 points
- 7 ft between points
- 5 ft between rows
- MW-1D 7 ft ug of HRC grid
- SP-2C 5 ft dg of HRC grid
- SP-3 wells are ~25 ft dg of HRC grid

# Chlorinated Ethene Concentrations for SP-3K



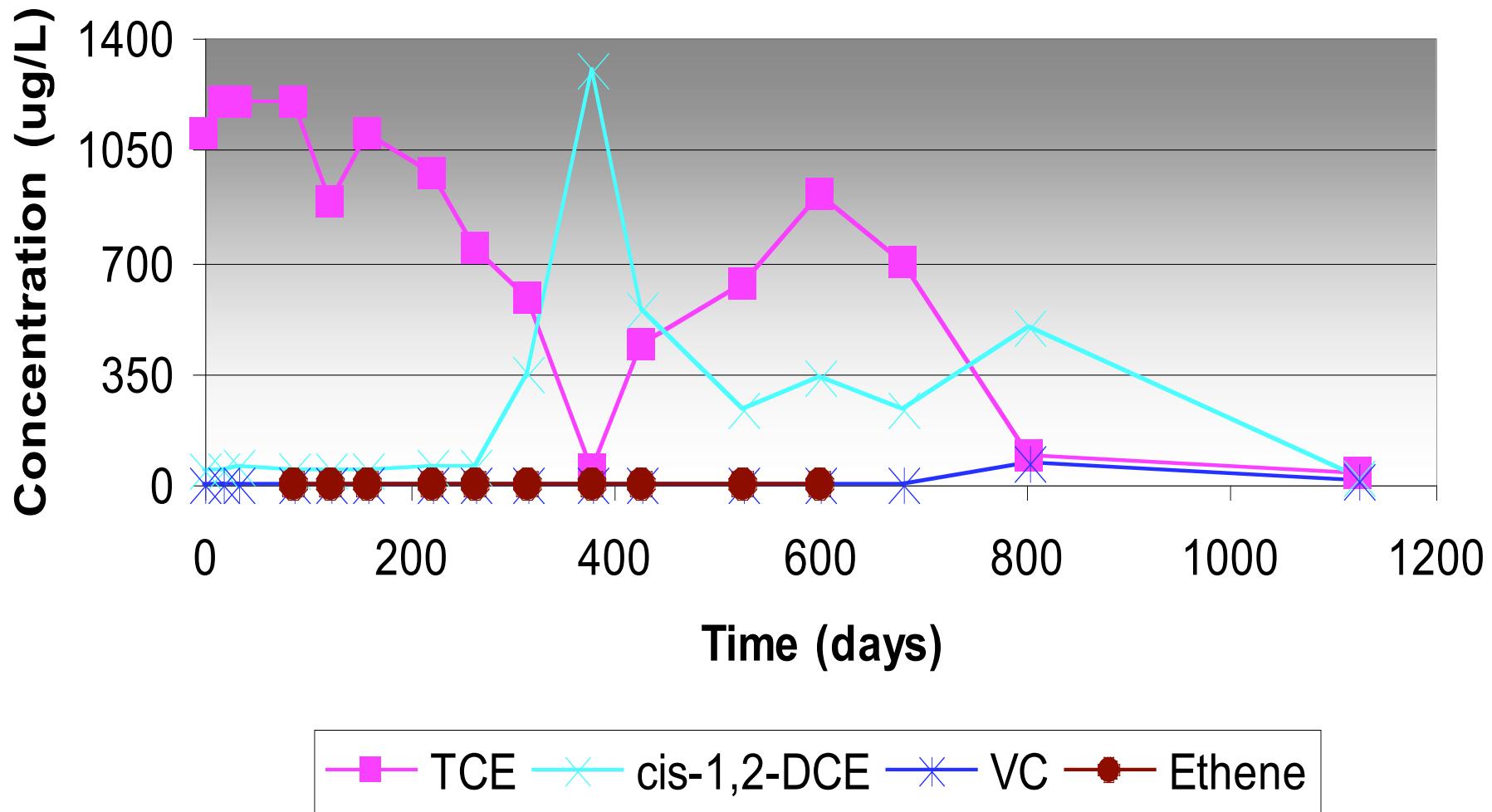
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# Chlorinated Ethene Concentrations for SP-3N

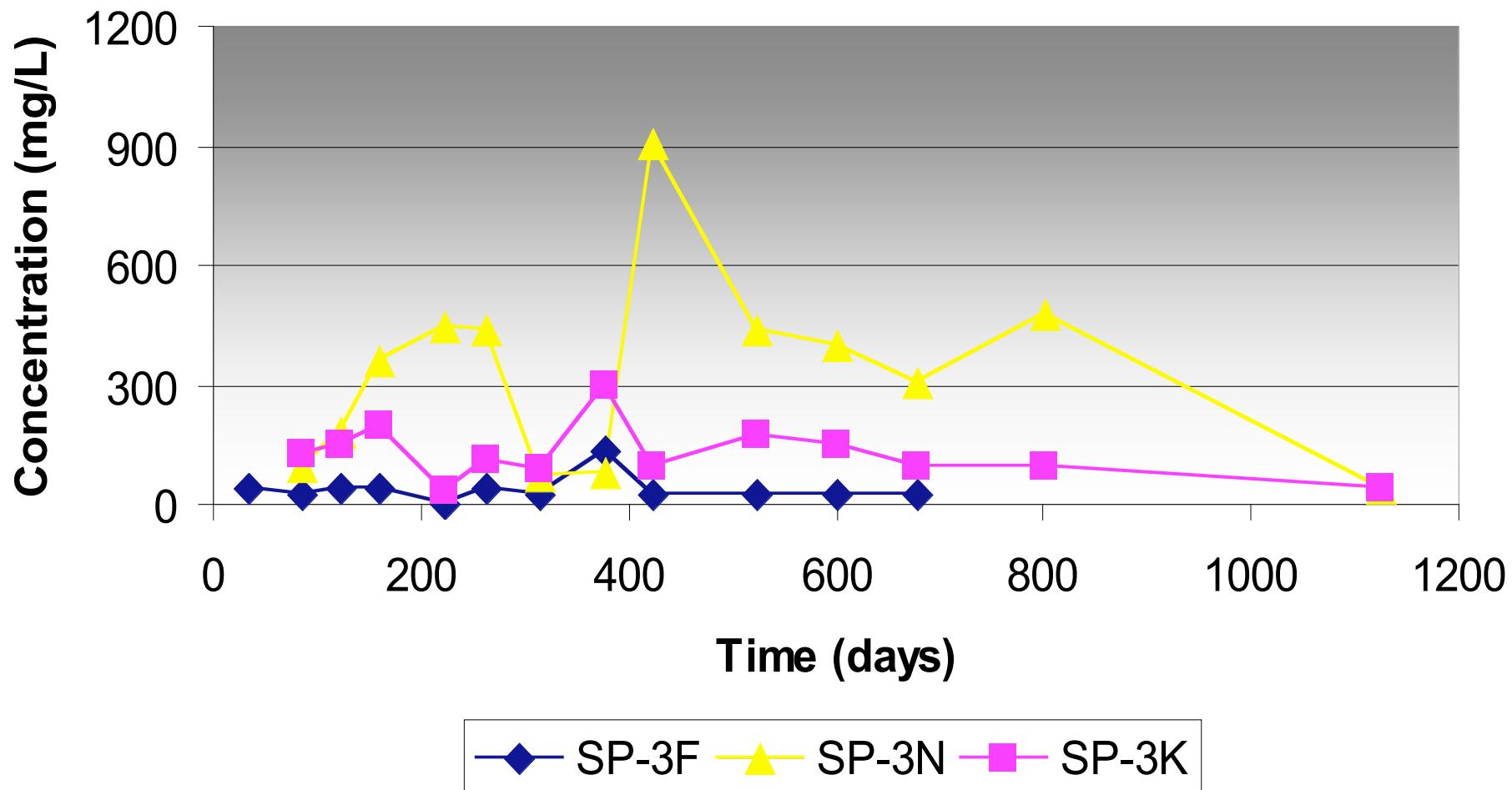


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# Chlorinated Ethene Concentrations for SP-3F



## Total Organic Acids in Row 3 Wells



# Oregon Department of Environmental Quality

Contact: Kevin Parrett

## Springdale Cleaners, Portland, OR

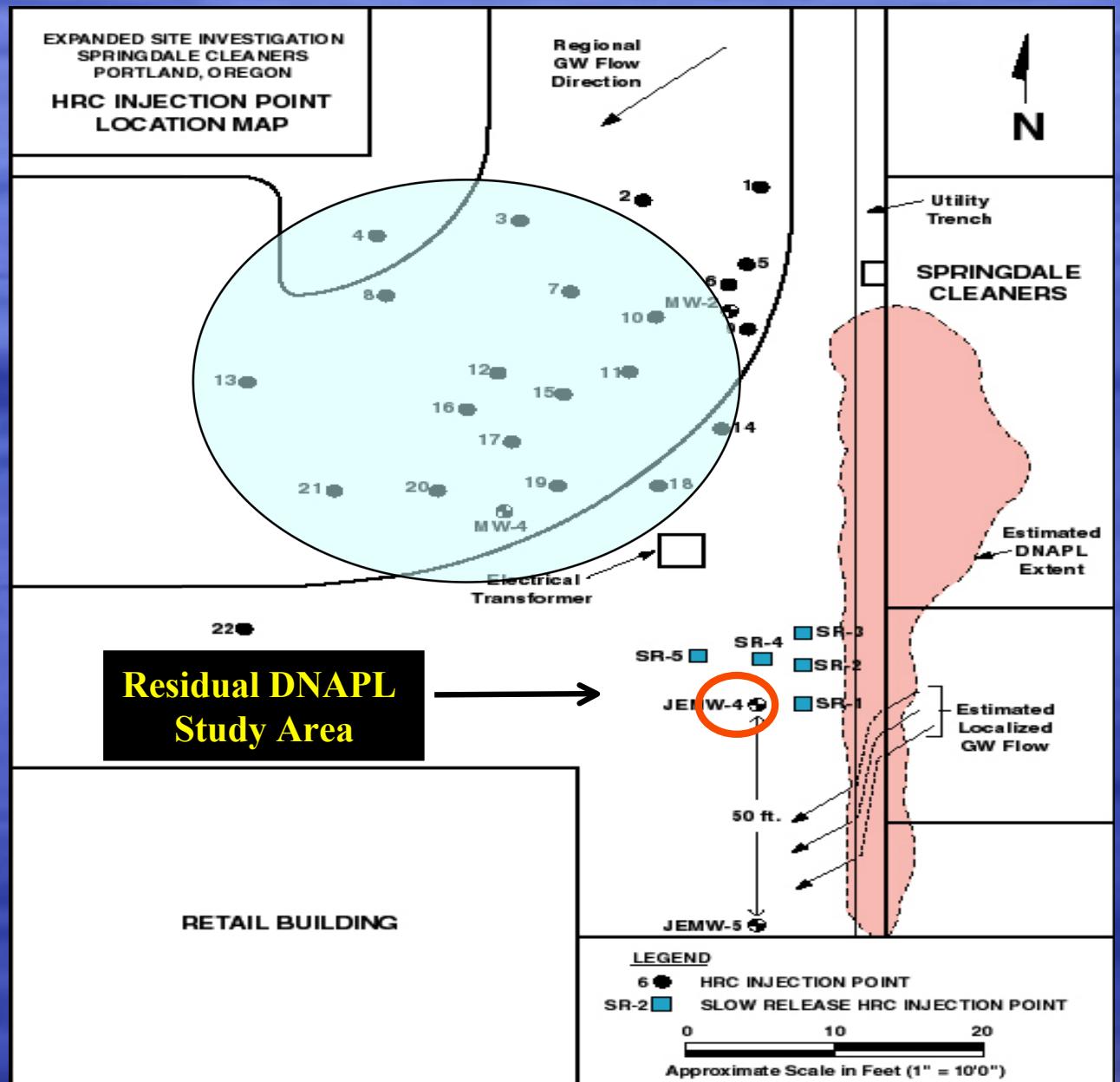
- Potential PCE DNAPL and associated dissolved phase plume present
- Treated by accelerated natural attenuation with HRC-X™ and HRC®



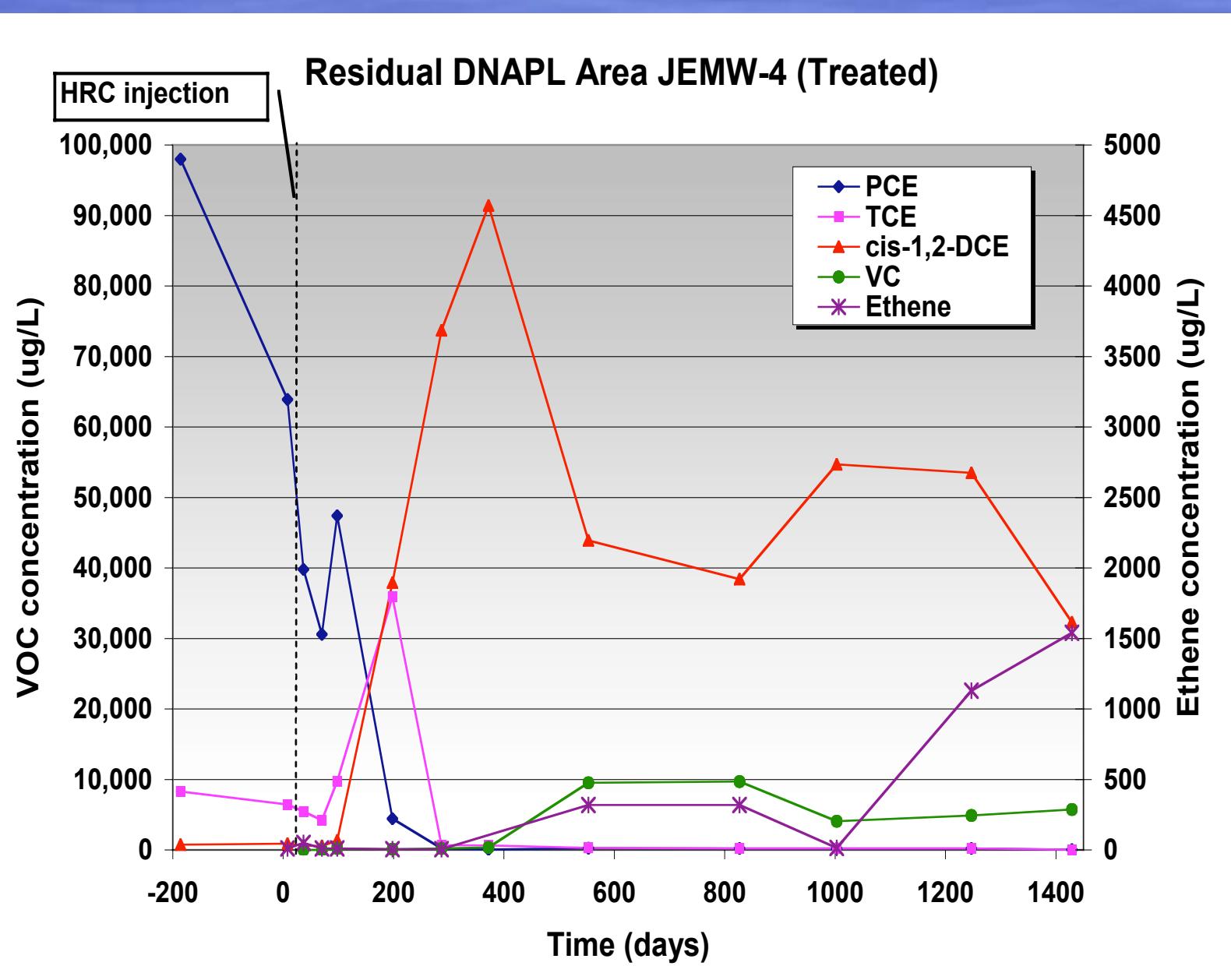


# Site Map

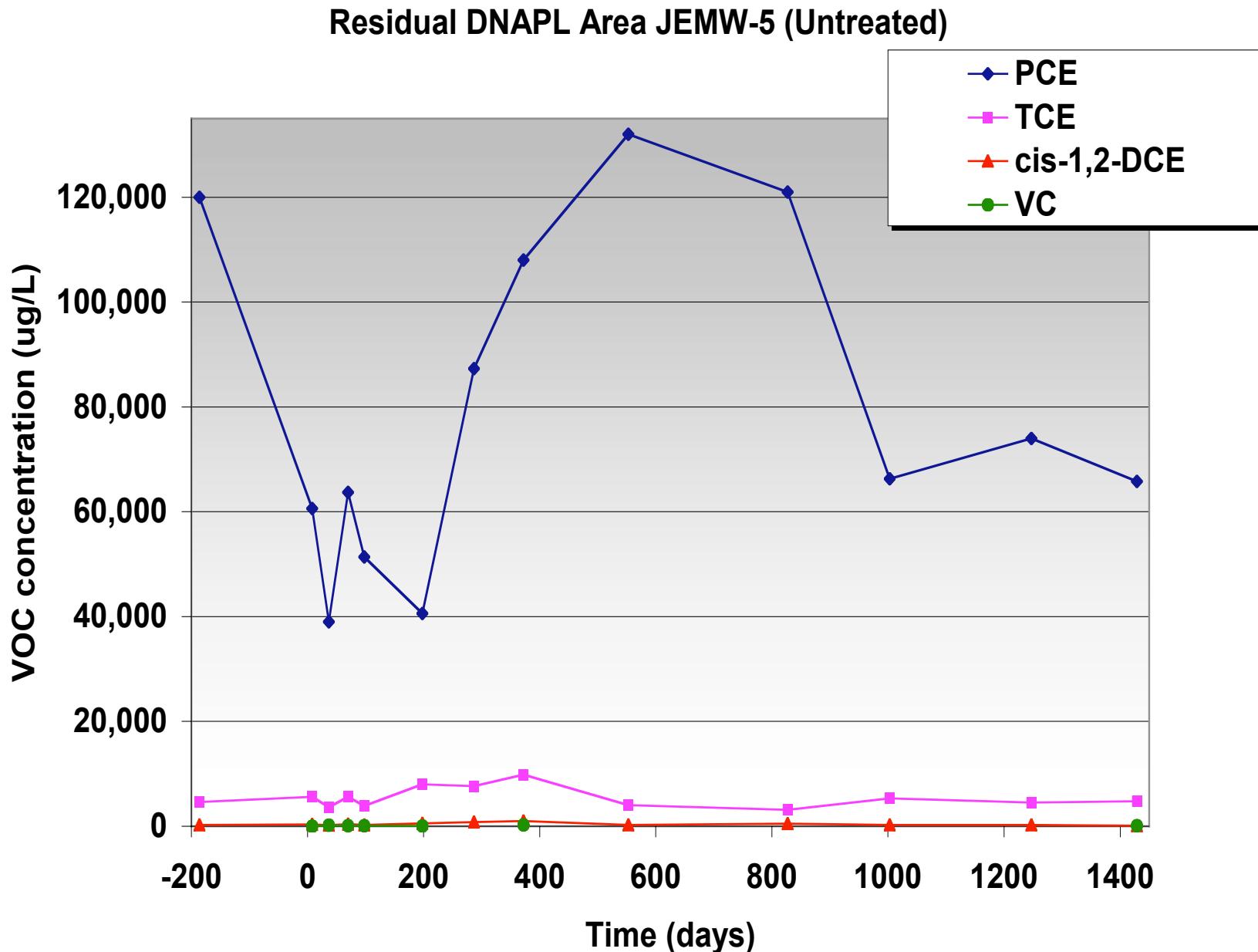
- Silty sand aquifer
- Depth to water: 2 - 7 ft bgs
- Groundwater flow to the west, 0.3 ft/day
- Utility trench along shopping center causes local flow to the south
- HRC-X barrier installed
- 700 lbs HRC-X applied to 5 points at 10 lbs/ft



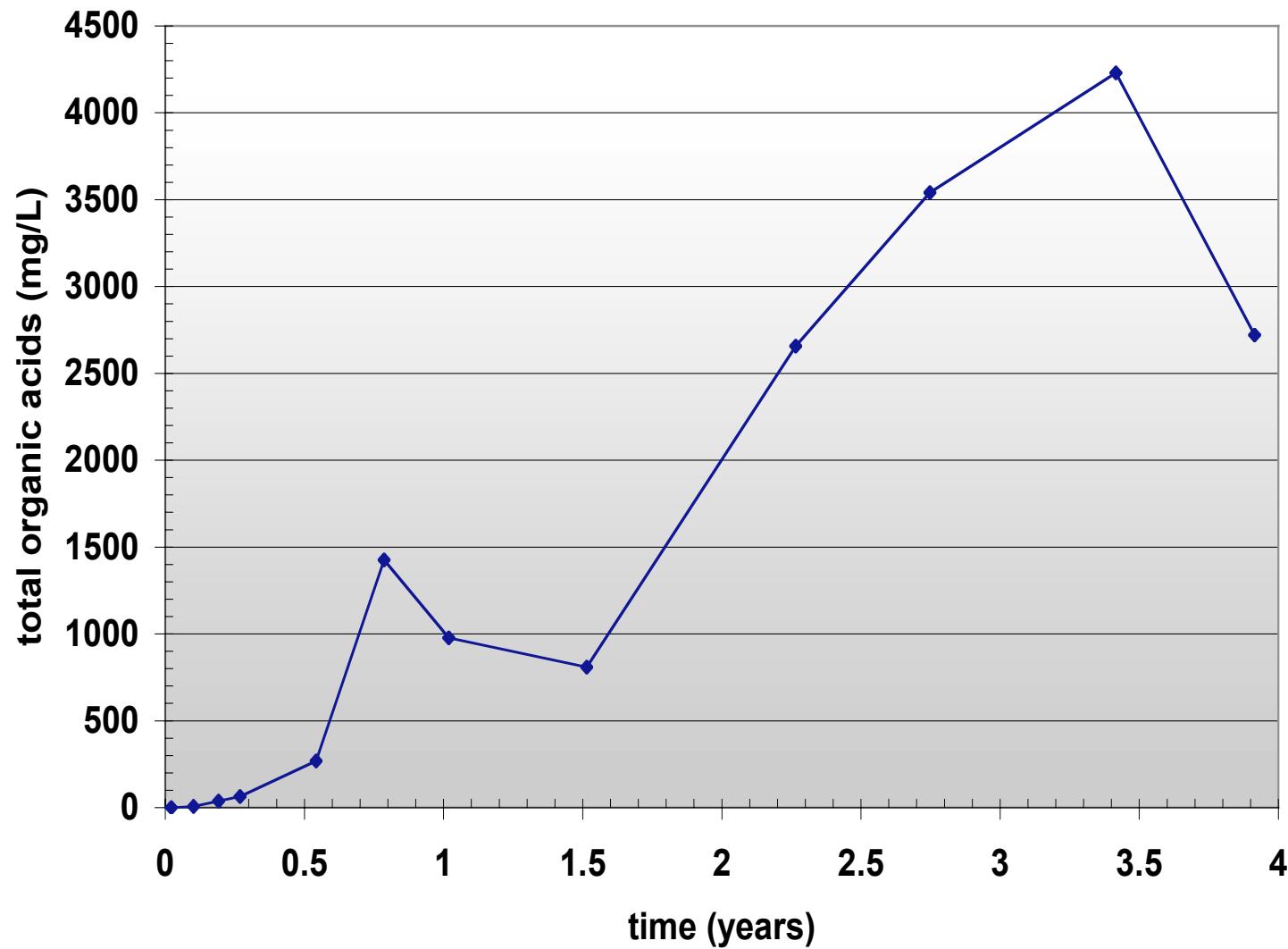
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### Organic Acids from HRC-X in JEMW-4 (Treated)



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## Conclusions of HRC-X Application

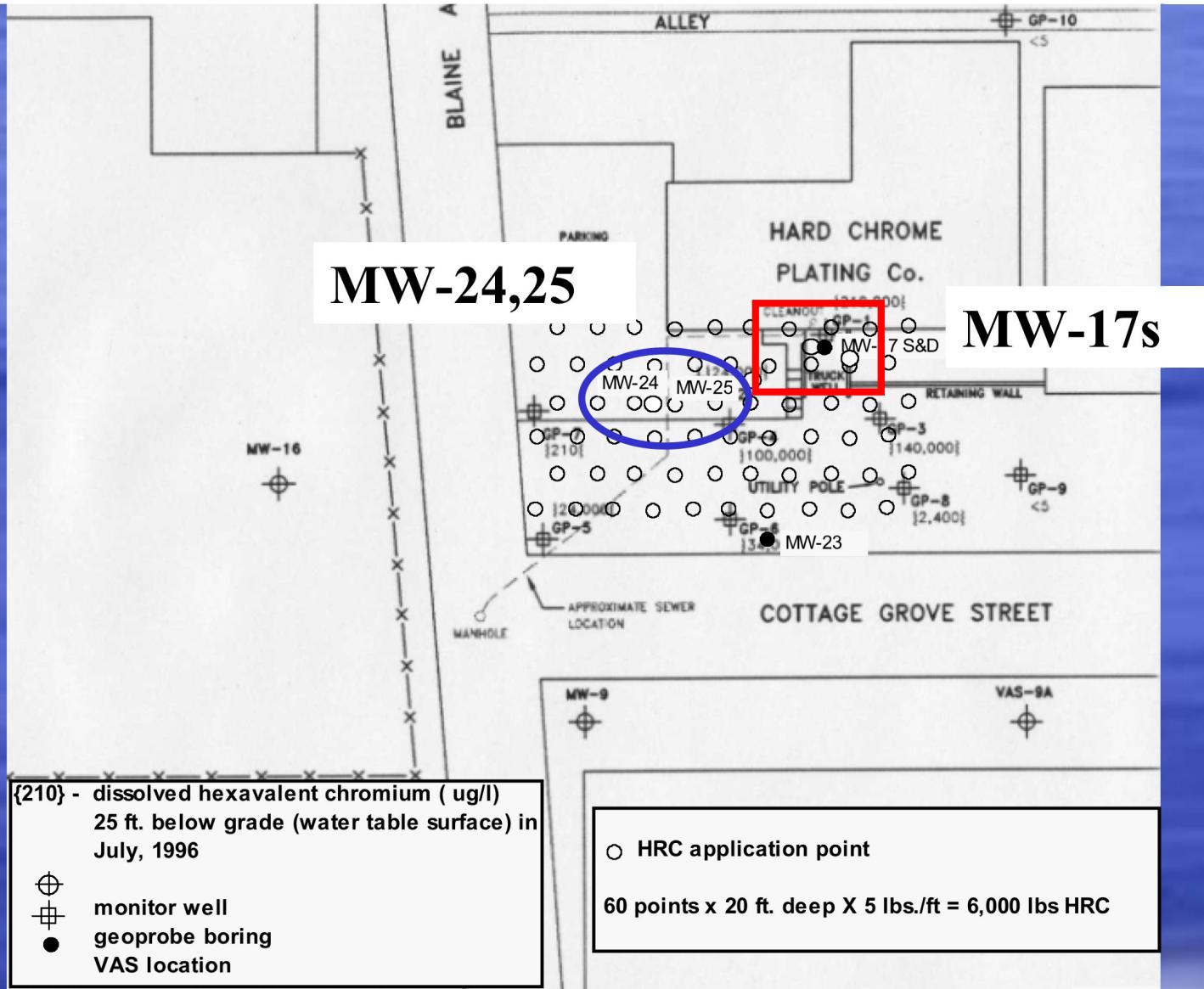
- The PCE concentration was reduced by over 99% in the HRC-X treated well (JEMW-4)
- Complete dechlorination occurred and significant ethene production was observed in well JEMW-4
- HRC-X has nearly a 4 year longevity in the subsurface at this site

# Chromium Remediation at an Active Plating Facility

- Light industrial area surrounded by residential property
- Well-sorted, medium to fine sand
- Groundwater at 25 ft bgs
- Groundwater velocity is 0.45 ft/day SW
- Hexavalent chromium plume with historical concentration in the 60-140 mg/L range

# HRC Application

- 100 lbs of HRC/point in a 60 point grid
- Points on 10 ft centers
- 5 lbs/ft applied from 45 to 25 ft bgs



SAMPLE DATE:  
July 16 & 17, 1996

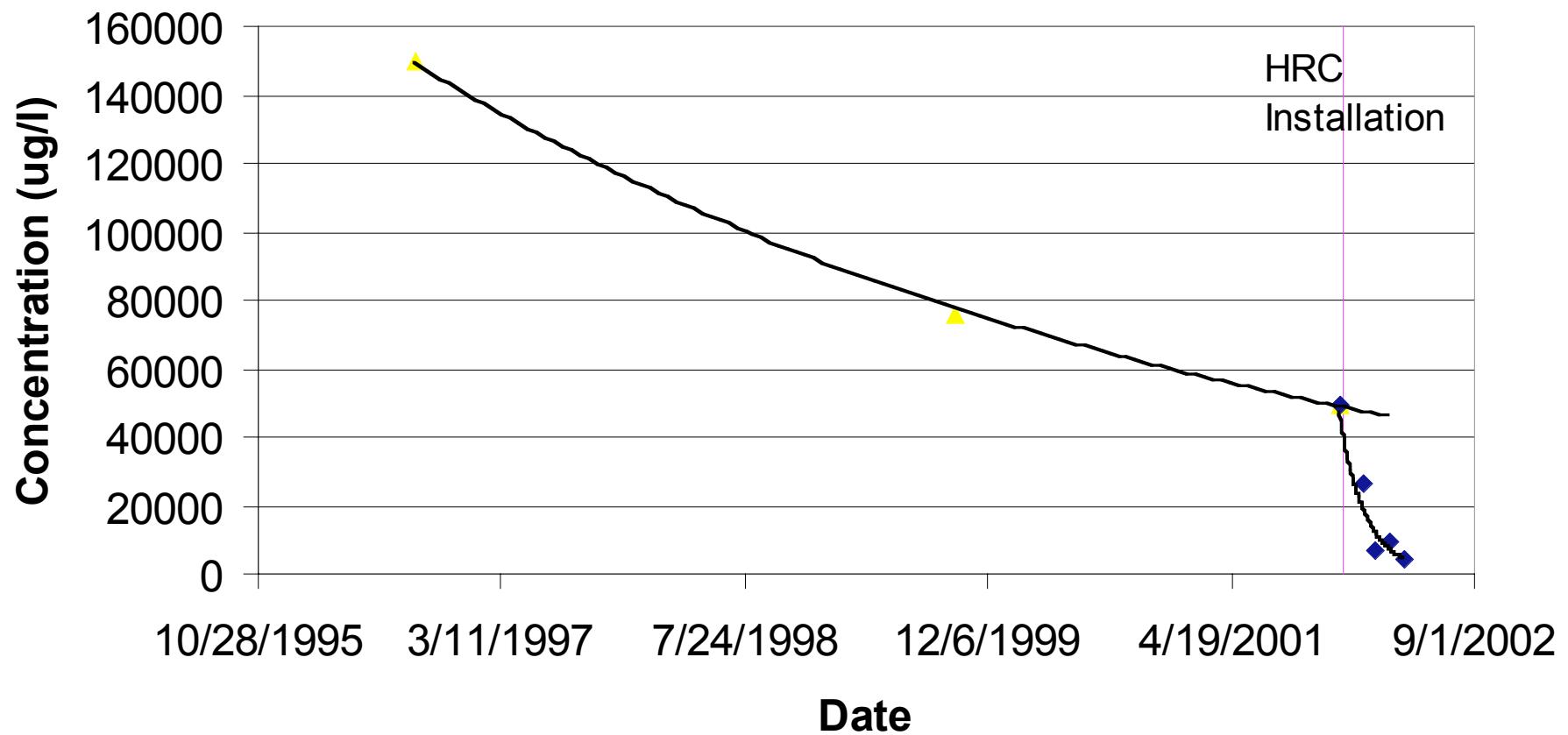
Scale: (Ft.)  
0 25 50

## GEOPROBE LOCATION MAP SHOWING HEXAVALENT CHROMIUM IN GROUNDWATER

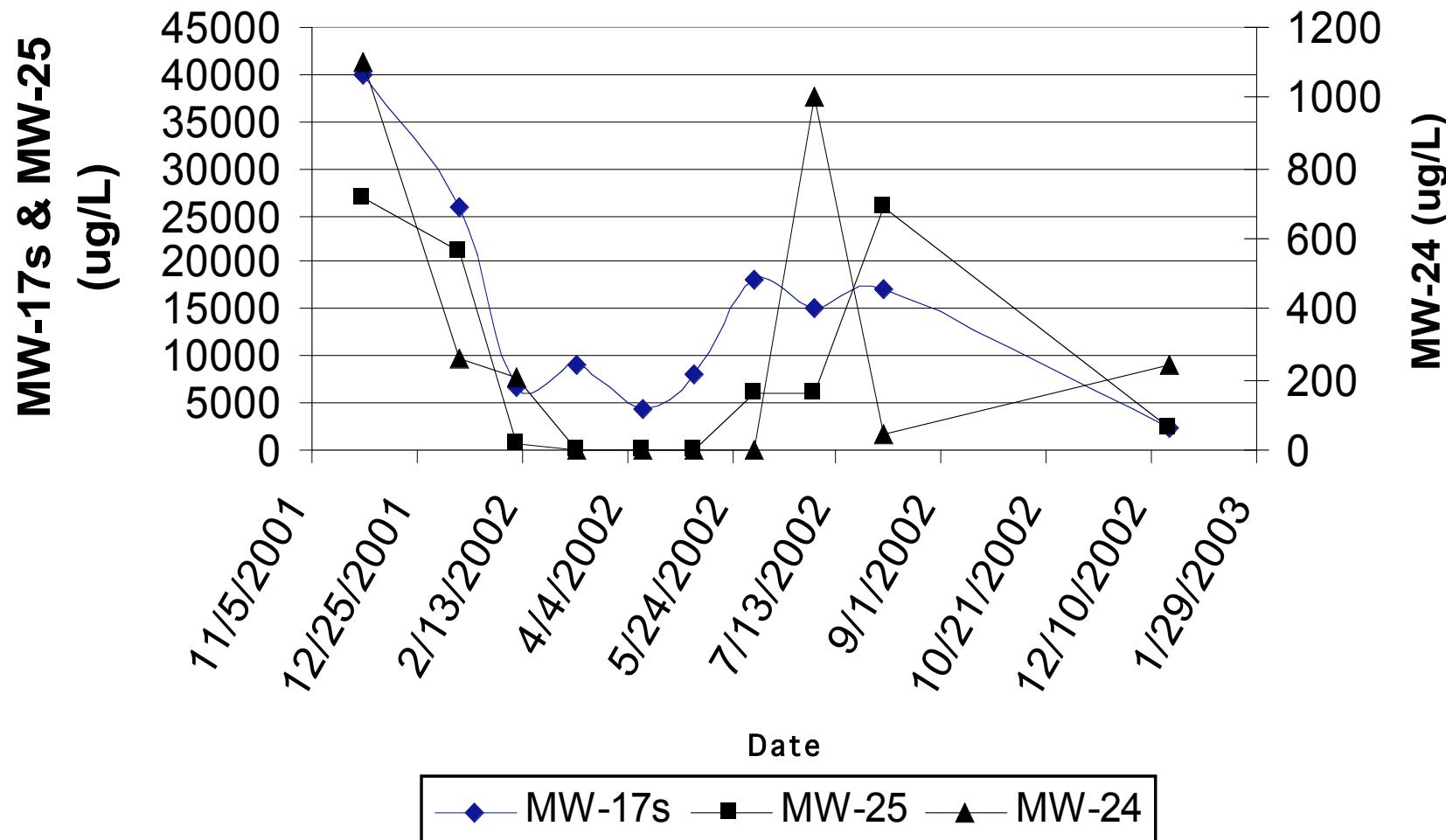
BERKEY STREET AREA SITE  
GRAND RAPIDS, MI

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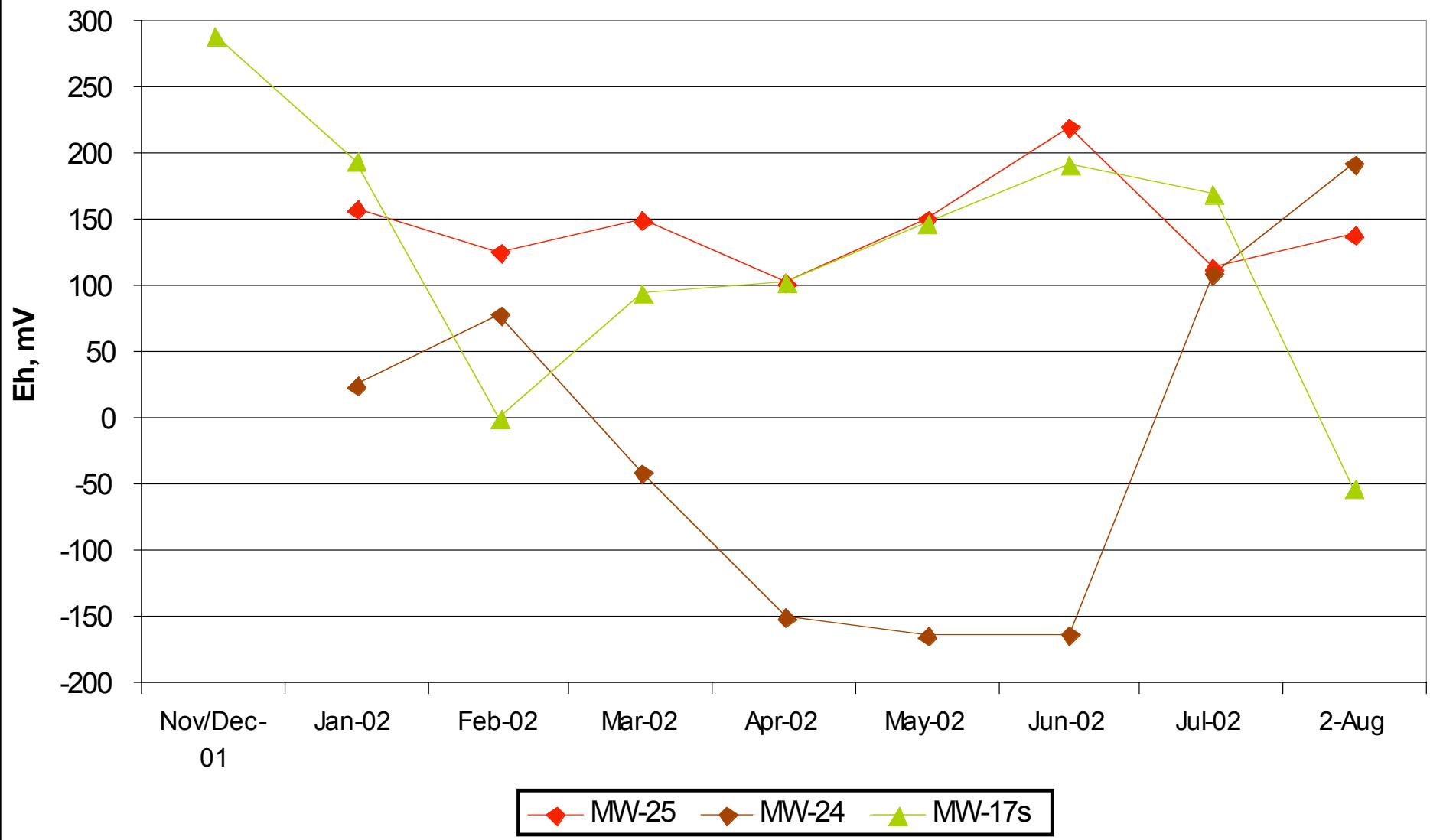
# Hexavalent Chromium in Well 17s



# Hexavalent Chromium Concentrations



**Figure 5: Eh Trends**  
**Berkey Street Site**



# Summary

- 80-90% hexavalent chromium decrease in treated wells
- Total chromium tracked with hexavalent chromium
- Hexavalent chromium removal rates increased after HRC injection
- Low concentrations of organic acids in key wells
- Decreasing ORP observed in some wells